COAST STABILIZATION AND PROTECTION ON LONG ISLAND

Prepared by
The Center for the
Environment and Man, Inc.
under
Sea Grant Project GH-63
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

CEM-4103-456
February 1972

F. L. Bartholomew
W. V. McGuinness, Jr.

Regional Marine Resources Council

A COMMITTEE OF THE NASSAU-SUFFOLK REGIONAL PLANNING BOARD

COAST STABILIZATION AND PROTECTION ON LONG ISLAND

Prepared for the
Marine Resource Council
Nassau-Suffolk Regional Planning Board
under
Sea Grant Project GH-63
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

CEM-4103-456
February 1972

THE CENTER FOR THE ENVIRONMENT AND MAN, INC.
275 Windsor Street Hartford, Connecticut 06120

FOREWORD

This report is part of a series prepared by The Center for the Environment and Man, Inc., for the Regional Marine Resources Council of the Nassau-Suffolk Regional Planning Board under the continuing program: The Development of Methodologies for Planning for the Optimum Use of the Marine Resources of the Coastal Zone. The program is being funded in part by the Sea Grant Program of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and is structured into six functional steps:

Functional Step One (Problems). Identifies, classifies and briefly analyzes the problems that confront planners and decision makers with regard to the area's marine resources.

Functional Step Two (Knowledge Requirements). Categorizes the data and knowledge necessary for making sound decisions with regard to the use of the marine resources.

Functional Step Three (State of the Art). Assesses the availability and adequacy of the necessary data and knowledge.

Functional Step Four (Knowledge Gaps). Determines necessary data collection and research activity.

Functional Step Five (Data Collection and Research Program). Formulates a priority-oriented, marine-related data collection and research program and monitors its implementation.

Functional Step Six (Management Information System). Develops a system for organizing the data and knowledge and provides analyzed information to marine planners.

Functional Steps One and Two were completed in previous reports of this series [1a, 1b and 1c][1/].

1/ Citations in brackets are listed in Appendix A.

The current report on dredging is one of seven which together constitute Functional Step Three. Two of these seven reports were completed previously for coastal water quality standards [1d] and for estuarine models [1e]. Four reports addressing selected priority problems are currently being prepared simultaneously for integated water supply and waste disposal [1g], coastal stabilization and protection [1h], dredging [1i], and wetlands [1j].

The current report and all previous reports will contribute to future reports in this series on the state of the art [1k] (Functional Step Three), a proposed research program [1ℓ] (Functional Steps Four and Five), guidelines for planning and policy formulation [1m], and a marine management information system [1n] Functional Step Six).

In the preparation of this report, we are indebted to many individuals who comment on early drafts. Particularly prominent among this group were Alan Richmond of the Council; Morris Cohen of the North Atlantic Division of the U.S. Army Corps of Engineers; and Stanley Maisel, Gilbert Nersesian, and F. R. Pagano of the Corps' New York District. The last four promptly and fully responded to every request for information on the Corps shore stabilization and protection role on Long Island.

TABLE OF CONTENTS

SECTION 1 - INTRODUCTION

1.1 PROBLEM DESCRIPTION

As the term is used herein, a "problem" exists when conditions are not what people would like them to be. The objectionable conditions may be caused by natural forces, or by human activities, or by both. The objectionable conditions may be potential, new or long-standing; sudden or chronic; severe or mild; highly visible or subtle; widespread or local. The importance of a problem lies in the significance of the undesirable conditions to the beholder. With different people having different objectives and desires, one person will see a problem in a given set of conditions that to another are quite acceptable.

Dr. McCormick at Southampton College makes the point that Long Island shores have been receding for thousands of years as part of natural geologic change [2]. To him, this is not the problem with which we can expect to deal, except to adjust to it. Because of the slow rate of recession, adjustment to it might not be too difficult. With the introduction of human activity at the shoreline, however, more rapid changes have been superimposed and the impact of these changes has been intensified; they can, for example, cause potentially direct and relatively sudden impacts upon life and property 1/. To Dr. McCormick, these changes and their impacts are problems with which we can deal. The definition of a problem here will follow this line of reasoning.

The problem considered in this analysis is defined as "how to stabilize and protect the coast of Long Island 2/ in an economically, socially and environmentally acceptable way for now and for the future." It will involve an evaluation of what shoreline conditions are desirable, what can feasibly be done to promote these desirable conditions, and what undesirable secondary or side effects must be avoided or minimized.

1/ Also the view of Clarence Renshaw [3].

2/ For brevity and readibility, the term "Long Island" will often be used throughout this analysis in place of the technically correct but cumbersome "Nassau and Suffolk Counties' portion of Long Island, New York," or the synonymous "bi-county area." With a land area of about 1,200 square miles and 2.5 million residents, Nassau and Suffolk Counties together account for 86% of the island's total land area and 36% of its total 1970 population. The other two counties on Long Island are Kings and Queens. Both are part of New York City. Population is relatively stable in Kings-Queens, but it is increasing rapidly in Nassau-Suffolk.

The perspective for ascertaining "desirable conditions" and "undesirable secondary effects" is that of comprehensive planning which explicitly takes into account the desires of all major users of the coastal zone.

1.2 THE PROBLEM IN NATIONAL PERSPECTIVE

According to the evaluation in the National Shoreline Study [4], the bi-county area leads the nation in the magnitude of its coastal stabilization and protection problems. This unwanted distinction stems from the substantial rate of erosion here[1/] combined with the very high values associated with the shoreline in this densely-populated, highly-developed area[2/].

Table 1 brings out the relative severity of the local problem. Note, for example, that the region and the bi-county area respectively contain only about 10% and 0.6% of the nation's total shoreline. Yet, they include 40% and 10% respectively of the nation's critical erosion. The bi-county area contains about as much Priority-1 erosion as the rest of the nation combined. Nationally, the cost of halting critical erosion has been estimated at $1,800 million, of which $320 million is for the bi-county area.

1.3 POTENTIAL USERS OF THIS REPORT

This report is prepared primarily for the use of the Regional Marine Resources Council and its parent body, the Nassau-Suffolk Regional Planning Board. As such, it is an overview and seeks to provide a perspective useful for formulating broad public policy. In developing this overview, considerable information is provided that should be useful to other bodies such as the departments of public works of each county and several federal agencies. The report is developed in such a way as to maximize its contribution to later reports in this series. Although a problem of this type is primarily

---

1/ More rapid local erosion occurs in some other parts of the nation, but the coastal values associated with these losses are usually lower.

2/ This is especially true in the more-populated western end of the island. For example, with respect to beach recreation alone, the U.S. Outdoor Recreation Review Commission has stated that "The fantastic crowding of beaches close to New York City renders superfluous all surveys, studies and analyses that seek to prove that more close-in beaches are needed. It would be impossible to develop enough close-in beaches to meet the present demand, let alone create an oversupply for the future." [4c]

TABLE 1

EROSION OF THE NATION'S COASTLINE

(in miles)

Location	Length 1/	Condition			Critical Erosion Priorities 2/			
		Non-eroding	Eroding 2/		Priority 1	Priority 2	Priority 3	Priority 4
			Non-critical	Critical				
U.S., including Alaska	84,240	63,740	17,800	2,700	190	1,030	691	784
U.S., excluding Alaska	36,940	21,540	12,800	2,600	190	1,030	691	689
North Atlantic Region 3/	8,620	1,160	6,370	1,090	130	442	248	274
N.Y. State, Atlantic	638	0	338	300	101	115	84	0
Nassau-Suffolk	551	0	272	279	91	104	84	0

1/ Shoreline length increases greatly with the detail with which coastal configurations are measured. For consistency, the lengths used here, and throughout this report, are those reported in The National Shoreline Study.

2/ Priority 1 indicates "areas where continued critical erosion is likely to endanger life or public safety within 5 years." For other definitions, see Table 4 in Section 2.3.

3/ Maine to Virginia, inclusive.

Sources: [4a, 4d, 5]

local in nature, the processes involved, the solutions and the methodology employed should be applicable to similar problems elsewhere.

The people who use this report will have some role of influence in the planning function for the regional development of areas on Long Island where the activities or the geography interact with marine affairs. The user may be only a private citizen who, as a member of a group whose interests are involved in regional development plans, wants to bring to bear what weight he can in public hearings, and employs this information to help establish and test his position on coast stabilization and protection problems. At the other end of the spectrum of involvement is the full-time employee or executive of a planning body which contributes the original concepts for a comprehensive approach to regional planning involving the shore.

Resources in time, money, equipment and even sand are limited. Just because a beach can be preserved or restored does not justify a plan to do so to maintain the status quo, or to bring back the "days of yore." Some shoreline can be allowed to erode away without significant loss to human use; while some, though perhaps more difficult to save, must be given tender loving care at almost any cost. The user of this report will sometimes be one who must help make the decision as to whether a given reach is in the former or the latter category.

1.4 CHARACTERISTICS OF THE DECISIONS REQUIRED

The basic decision is where and how should man intervene to influence the natural phenomena that affect the physical stability of the shore and adjacent areas. The decision is based upon an evaluation of the consequences of inaction and the consequences of inaction.

Actions taken in coast stabilization and protection are the result of these decisions, which take into account both the natural phenomena and the human activities affected by them and by the intervention being considered. Secondary effects of dredging and dredging spoil disposal, for example, may offset the benefits gained for the shore and its use. Management techniques [4c] which influence people in their use of the shore through such devices as permits, zoning or acquisition, will be considered among the alternative courses of action available to the decision maker.

Involving the public in the decision process through such things as town meetings or opinion polls will not only provide useful information, but may avoid some damaging opposition to the decision. Decisions as to the appropriate agency or institution to call upon both in planning and execution of a project plus the fair allocation of costs will also be important to success.

1.5 SUGGESTED GENERAL APPROACH TO THE PROBLEM [1/]

1.5.1 Understand Shore Processes

A general understanding of the principal natural forces and human actions that independently or in conjunction shape the shore is a fundamental beginning point in identifying and solving coastal stabilization and protection problems.

1.5.2 Observe the Usage of the Shore

The current usage of the shore and adjacent areas should be recorded systematically by category—such as commercial fishing, sand and gravel extraction, waste disposal, recreation, aesthetic satisfaction, transportation and land development—and projections should be made of future usage. The usage patterns will take on added perspective if they are analyzed in context with the broader information base derived in the process of bi-county comprehensive planning. This includes socio-economic trends; population, affluence, liesure, transportation and land development patterns, and public values such as appreciation of the natural environment.

1.5.3 Observe the Condition of the Shore

Parallel to the usage information, an up-to-date inventory of shore conditions should be maintained and analyzed in order to make projections of conditions to be expected in the future. The inventory should emphasize conditions in areas subject to significant physical change, such as around inlets and bluffs and also in areas subject to especially heavy human use, such as the barrier beaches, inlets and backbays.

1.5.4 Determine Where Usage Requires Preservation or Change of Present Shore Conditions

Usage is ordinarily evaluated in human terms, but even then the functions that a wetland performs for wildlife are of value to the human community, if only indirectly.

[1/] A more complete treatment of this type of approach to the problem will be found in Shore Management Guidelines [4c].

Projected demands will always be the basis for evaluation, and with limited resources an ordering by priority may be necessary. Requirement for preservation or change to satisfy demands can be stated fairly clearly, but the decision as to whether or not the requirement is to be met will depend upon how it fares in comparison with other requirements and the ways in which they may be satisfied.

1.5.5 Examine Alternative Courses of Action

One alternative that should always be considered is to do nothing to arrest or control natural or human change and usage. The other alternatives require some action employing engineering or management techniques, or both in a complementary way [4c].

Engineering techniques involve physical intervention in the interaction of sea and shore. They employ beach nourishment, dune stabilization, vegetative cover, breakwaters, jetties, groins, bulkheads, revetments, seawalls, ditches, dikes and hurricane barriers. They are described briefly in Shore Protection Guidelines [4b] and in technical depth in Shore Protection, Planning and Design [6n].

Management techniques influence people in their use of land along the shore. They employ acquisition, private agreements, taxation and cost sharing policies, planning maps, policies on protection of private property, zoning, subdivision regulation, building codes, ordinances, permits, orders, condemnation and inverse condemnation. They are described briefly in a shore context in Shore Management Guidelines [4c].

1.5.6 Examine the External Consequences

Comprehensive planning recognizes the interrelationships among all planning activities and the many facets of life in the region. Any program designed to produce a desired result will have incidental effects upon other activities and conditions as well. A jetty extended from the mouth of an inlet will help keep the inlet open, but it will also trap sand needed for renourishment of downdrift beaches. In choosing a course of action, the external consequences of each alternative in the given situation must be recognized and weighed. Often the impact may extend into the social or economic sphere, such as it would if Shinnecock and Moriches Inlets were allowed to close with major adverse impacts on the shellfish industry[1]—and upon all other users of the bay that depend significantly upon the flushing action of the tides. This, of course, is an extreme example. Judgment is always necessary to decide whether the anticipated benefits of action (or inaction) are worth the associated costs and side effects.

1.5.7 Set Up a Program of Compatible Projects

In the general case, where there is more than one problem to be considered and more than one alternative course of action to take for each, the most desirable alternative will have been selected for each project. The integration of these activities into a program within existing funding constraints may reveal conflicts where one project is competing with another for the available resources. In such an event, one of the alternatives rejected earlier may prove to be more desirable than the one chosen as optimal when the project was considered by itself. The integration of all projects into a program is a beginning, but the formulation and execution of the program are really only two parts of a continuing process. During execution, unforeseen events will take place on the projects and in peripheral related areas. Monitoring of the projects and of public opinion in related matters will provide valuable feedback that may indicate a need to modify the program as time goes on.

---

[1] The dramatic relationship between the several openings and closings of Morishes Inlet and the fluctuating viability of the oyster and hard clam industries has been described in an earlier report of the Council [7a]. Sudden major changes were observed in salinity (12 to 30 ppt), concentrations of dissolved nitrates and phosphates, algae formations, and predatory populations. Associated sharp rises and declines in the populations of oysters and hard clams ranged from virtual extenction to rarely-found abundance.

SECTION 2 - ANALYSIS

This analysis first outlines major dimensions of the problem. It then examines more closely the relevant natural phenomena and the forms of human intervention. It next depicts ownership, critical erosion and damages. Lastly, it examines usage patterns, shore conditions, problems and alternative solution in each of five delineated reaches.

2.1 PROBLEM DIMENSIONS

Following the structure established in one of the earlier reports of this series on Functional Step One [1a], selected dimensions of this problem are outlined below in general terms.

2.1.1 Causal Agents

The principal natural causal agents are the winds and tides which interact with local coastal configurations and soil properties. Winds help shape the dunes along the beach. Even more importantly, winds over a sizable fetch of open ocean play a key role in generating and magnifying waves and swells. The wave energy causes erosion and accretion by impinging directly upon the shore, and also by inducing a longshore current parallel to the shoreline. Tidal currents, influenced by tideland topography, cause scouring and shoaling, particularly near inlets.

Whether they are caused by wind or tide, currents transport fine-grained soil particles. The faster the current, the larger the grain size it can transport. When the current slows, as when it leaves an inlet mouth or returns from the beach shore, the sand grains precipitate out in gradually decreasing size, forming a shoal or a bar. If no sand is brought in to replace that carried away, erosion occurs.

Two natural processes can provide replacement sand—the erosion of headlands and the river transport of sediment from the uplands. Only the former is significant on Long Island. Once the replacement sand reaches the shore, it is distributed laterally by littoral drift, the process induced principally by waves hitting the beach at an angle.

Man is a major causal agent when he blunts or reinforces the forces of nature so that they produce undesirable conditions. When he steepens the beach profile, he decreases its natural capability to absorb wave energy without erosion. When he builds groins, jetties or other coastal structures, he may trap littoral drift causing accretion updrift and erosion downdrift. When he alters channels, particularly near inlets, he can change currents and consequent scouring and shoaling patterns. When he removes or degrades dunes, he increases the likelihood of inland inundation during severe storms. When he fills in shorelands, he decreases the areas of backbays inundated by the tides with consequent effects on tidal currents. Not all of these changes are "bad." That judgment depends upon what conditions are considered to be desirable. The point here is only that man can significantly affect shore conditions by the way he interacts with natural forces.

2.1.2 Environmental Conditions

The major natural and human causal factors outlined above affect environmental conditions principally by altering shore topography. Most conspicuously, the shoreline itself may migrate. The extension of Fire Island westward over the years is a dramatic example of such a change[1/]. Beaches accrete updrift of groins and jetties, and erode downdrift. Changes in offshore topography can be brought about by storm action and by dredging or sand and gravel mining. The gradual filling in of Hempstead Harbor to a point where much of it has now become tidal flats is another case of topographical change in the opposite direction trending towards wetlands formation. Moving inland, the growth and the destruction of protective dunes can be influenced by both man and nature. Wetland conditions can be completely and irreversibly changed by the placement of fill or dredging spoil.

These changed topographic conditions trigger many other secondary and subsequent effects. Topographic changes around inlets are particularly sensitive because the changes can influence currents, tidal elevations, biological exchange, sedimentation, shoaling, salinity and pollution levels in the backbays. Along the open ocean coast, changes in beach profile and protective dunes can greatly increase the vulnerability of the beach and upland areas to severe erosion and inundation during major storms, especially during hurricanes.

[1/] Some barrier islands off the southeast coast of the Delmarva Peninsula have been eroding at an average rate of a foot a week for the past century apparently entirely due to natural causes [8].

2.1.3 Effects

These changed environmental conditions caused by man and nature can impact significantly upon almost all coastal user groups but in different ways. Decisions on whether to "let nature take its course," or to reverse, retard or accelerate the changes brought about by natural forces must necessarily be based upon a careful examination of the effects on all user groups, individually and collectively.

Commercial finfishing and shellfishing users want stable or "improved" topographical biological and water quality conditions and will view coastal stabilization and protection in that light. These users are particularly interested in inlets, wetlands and shoal areas.

Sand and gravel mining will often be restricted to minimize environmental effects. Inlet configuration and related hydraulic effects control the flushing of backbays, a process of particular interest in resolving waste disposal problems.

Recreational uses of coastal areas are sensitive to changes in the size and characteristics of beaches, wetlands and boating channels. In recent years Jones Beach, Robert Moses and Sunken Meadow State Parks have been recording about 13, 2 and 2 million annual visitors, respectively[1/].

Marine transportation requires channels of adequate depth and width. The requirement is minimal on the south and east shores of Long Island but is important for approaches to some small harbors on the north shore such as Hempstead Harbor and Port Jefferson.

Shorefront development, particularly for residential, recreational and road building purposes, is strongly affected by the stability of the adjacent beach or protective barrier island.

2.1.4 Natural Environmental Characteristics

The shoreline of Long Island is characterized by a variety of environmental conditions. The south shore, exposed to the open ocean and the occasional hurricane,

---

[1/] Recreational usage is even more intense in the nearby, more populated counties of Kings and Queens. For example, Coney Island and Rockaway Beach each attract about 20 million visitors annually [4c].

has developed barrier islands protecting shallow backbays and extensive wetlands. Bays with similar shoreline are found between the eastern forks. The entire north shore enjoys conditions characteristic of a sound; the fetch that brings storm waves and hurricanes to the south shore is lacking there, and the littoral drift is less pronounced. Bluffs, with and without narrow beaches, are found along the north shore and on the South Fork.

2.1.5 Reasons for Dissatisfaction

Human dissatisfaction stems from conservation, aesthetic, economic, and social ethics.

Some people[1/] are dissatisfied with the present situation on the south shore and elsewhere from the standpoint of the disturbance of natural processes by human activities. They say our natural resources along the shores, in the wetlands and in the harbors are not being conserved—that the natural processes that give stability to the land forms and to the ecology of the island are being seriously affected through ignorance or lack of concern.

Another type of dissatisfaction arises out of the fact that the shore as a natural resource is not available to the public in many areas. Further dissatisfaction in this connection has come from the restoration and protection of privately held beach at public expense[2/].

In addition to the cost sharing problem just mentioned, there is an economic basis for dissatisfaction among landowners who now find they are facing possible restriction on the development of their own property—restrictions that were unheard of when they purchased it. In particular, this applies to the filling of wetlands for residential, commercial or industrial use, where the income from the property would, of course, be significantly greater.

1/ Including Dr. C. L. McCormick at Southampton College [9] and Dr. L. A. Sirkin at Adelphi University in Garden City.

2/ Now being modified in Suffolk County by an act amending the county law "to authorize the creation of county hurricane protection, flood control and shoreline erosion control districts." Zones of assessment may be established to allocate a portion of the costs among those benefiting from the project when the general welfare is not affected [10].

An economic basis for dissatisfaction is also found in the possible effects upon the shellfishing industry if the water quality in the bays, for example, is allowed to degrade through lack of control of the flow into the bay at the inlets and rivers. The desire of some fishermen to gain time by having quicker access to the Atlantic through a new inlet across the center of Fire Island, if satisfied, will have an uncertain economic effect upon the shellfishermen who operate in the bay; the inlet could alter for better or worse the salinity or tidal patterns of bay waters.

2.1.6 Jurisdiction

Responsibility for coast stabilization and protection is shared. For coastal erosion, federal cost sharing for approved projects increases with the extent of public use of the protected area, and a detailed description of these policies has been published [23]. New York State provides 70 percent of the non-federal share of federal projects and 70 percent of the total cost of non-federal projects [8]. The federal government provides 100 percent of that portion of an approved project that involves hurricane protection or navigation. As a matter of policy, the federal government, through the U.S. Army Corps of Engineers, does not carry out a project or grant a permit for a non-federal project unless the project is supported by the state[1/].

2.2 NATURAL PHENOMENA AND HUMAN INTERVENTION

Natural processes are dynamic—they change with and without the intervention of man and they cause changes in environmental conditions such as coastal topography, currents and biological productivity, also with and without the intervention of man. As Figure 1 illustrates, the coastline of Long Island was in a state of rapid and constant change long before man intervened. Even today, many long, essentially-untouched reaches of the U.S. coastline are undergoing rapid change completely from natural causes.

Man finds this natural coastal instability inimicable to his aspirations for intense, high-valued use of the coastline. For the most part, he reluctantly has to subordinate his uses to the intensity of the natural processes, the magnitude of which he is unable

---

1/ "And so far as he knows, General Clarke (the Chief of Engineers) says, the Corps has never recommended approval of a project that was opposed by the governor of the state in which it was located." [11]

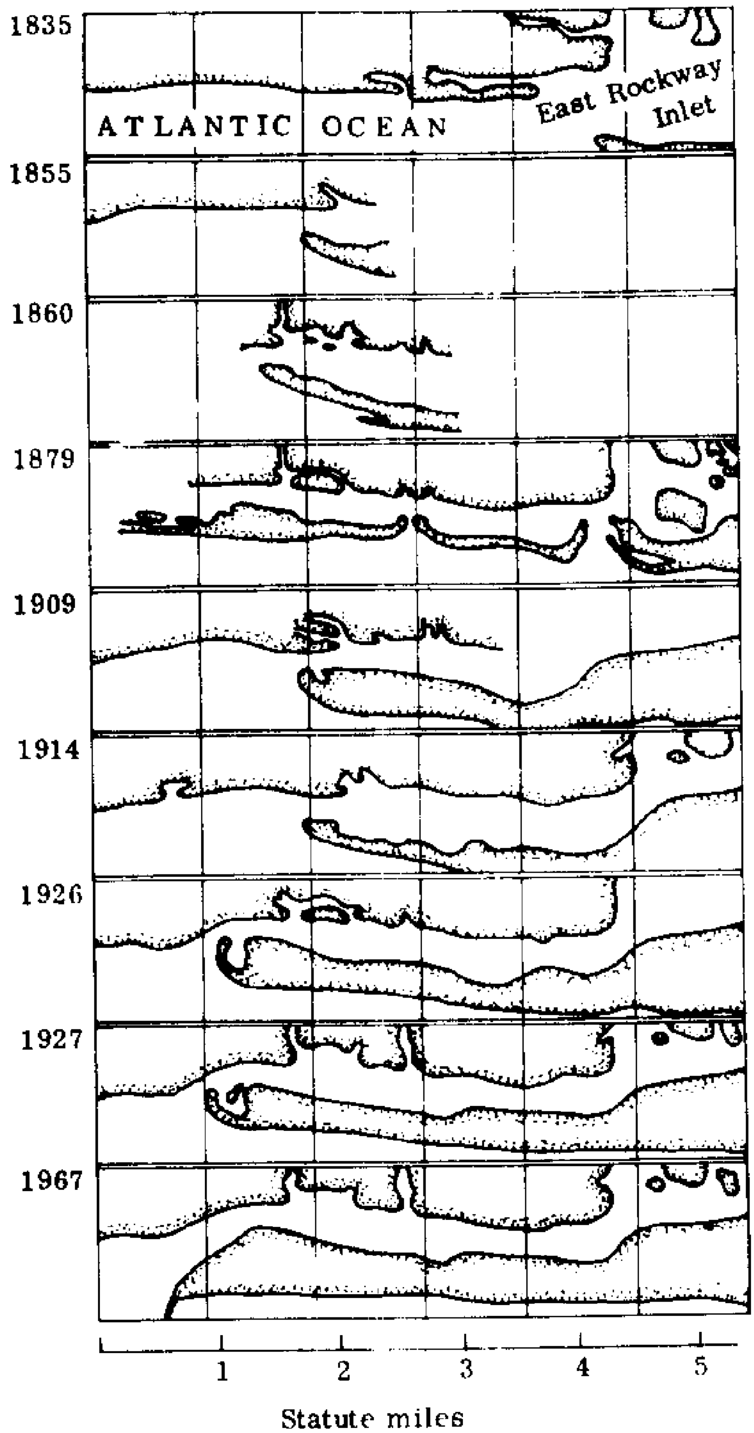


Figure 1

SHORELINE CHANGES AT EAST ROCKWAY INLET

Sources: 1835—1927 after U.S. Army, as presented by Wiegel [12]. 1967 from U.S.G.S. charts.

realistically to offset. So the main human response has been and probably will remain—to adjust his usage to coincide with natural realities. However, when the intensity of his usage—such as a multimillion visitor beach near a large city or a channel to a major port—is sufficiently high, man tries to alter natural forces. He usually has to accept only partial success. Figure 1 dramatizes the constantly changing configuration of the coastline in the vicinity of East Rockway Inlet. The shoreline has been more stable there in the past half century, but note the major accretion updrift from the jetty. Success at one location is sometimes partially paid for by increased erosion elsewhere. An example is downdrift erosion to the extent that it is not replenished in inlet stabilization projects.

Table 2 outlines relationships between selected natural phenomena and human activities that are characteristic of coastal stabilization and protection problems. The table serves as a road map for the expanded discussion to follow. Starting with the principal natural phenomena that shape the shore, the analysis considers the results of each phenomenon and of the human efforts that may be employed to make use of it, or to counteract it.

2.2.1 Wind

Wind is, of course largely responsible for waves, but the beach feels the wind and the waves as separate things, so that is the way they are treated here.

The wind has its effect upon all types of shores. The inclination of tree trunks on storm-swept coasts is clearly the work of the wind. But it is the sandy beach that finds the wind a most significant factor in its life.

The size of particles of a given density that a fluid can transport in suspension is determined by the speed of the fluid[1/]. When a moving mass of fluid, in this case air and called "wind," encounters a stationary obstacle, such as a building, a fence, or a mound on the surface, the fluid closest to the obstacle must travel farther in going around the obstacle than does the rest of the fluid that moves in a straight line downward. In doing so, and keeping up with the rest of the air mass, the air nearest an obstacle must

---

[1/] The particles are really falling through the fluid, but viscosity and turbulence of the fluid keep them suspended while they are transported.

TABLE 2

NATURAL PHENOMENA AND HUMAN INTERACTION

PHENOMENON / IMPACT	WIND	WAVES	TIDES	LITTORAL DRIFT
TYPE OF SHORE MOST AFFECTED	• Sandy shore	• Sandy shore • Beach bluffs or cliffs • Inlets along shore	• Inlets along shore • Bays • Estuaries	• Sandy shore • Inlets along shore
EFFECT(S) UPON SHORE	• Builds dunes • Causes dunes to migrate • Scours at structure foundations • Carries finest sand away	• Erode beach face in winter; restore it in summer • When severe, overrun barrier beaches, breach dunes, open inlets • Undercut bluffs • Produce littoral drift • Deposit sand on far side of structures, such as break-waters	• Produce shoals beyond ex-tremities of inlets • Provide stable saline con-ditions in estuaries and bays	• Gradually erodes sandy shore, but provides replenishment from updrift area unless trapped • Collects in inlets causing them to fill or migrate downdrift
WAYS TO DEAL WITH THESE EFFECTS	• Redevelop dunes with sand fences and plantings that entrap windblown sand • Rebuild dunes by physically adding sand or other select material • Stabilize dunes with natural vegetation, plantings and fertilizers and by controlling human activites	• Renourish beach periodically with sand from acceptable source • Avoid dredging sand from bars needed to replenish beach face • Construct -breakwater -bulkhead -sea wall -hurricane barrier • Foster dune growth • Stabilize dunes	• Dredge shoal sand periodically • Allow changes in inlet width or depth only when certain the conditions in the bay will not be sig-nificantly degraded	• Renourish beach periodically with sand from acceptable source to replace sand not replenished naturally • If sand is not needed at downdrift beach, construct groins or other structures to trap it when needed to broaden or maintain a beach • Dredge the shoal if necessary to keep the inlet open • Construct jetty to trap sand before it enters inlet • Provide sand bypassing system
SECONDARY CONSEQUENCES	• Sand starvation downwind • Prevention of encroachment by migrating dunes or other windblown sand • View obscured by dunes	• Restriction on source areas for dredging • Accretion of sand on lee side of breakwaters causes sand starvation elsewhere • Hurricane barrier may cause storm surge on ocean side, and alter currents in a harbor by channeling the ebb and flow at its entrance • Dunes can restrict view of the sea	• Desirable spoil deposition areas must be found for the sand dredged from the shoals	• Sand starvation downdrift from groins and jetties • Desirable spoil deposition area must be found for the sand dredged from the inlet

travel faster as it goes around the obstacle. Going faster, it can pick up more sand. It scours sand from the immediate vicinity of the obstacle, carries it so long as its speed is great enough, and drops it as soon as it resumes the slower speed of the air mass itself.

When a mound begins to build on a sandy beach—perhaps first shaped by the waves, swells or tides or even piled there by a bulldozer—the wind passing over it will accelerate as it encounters this detour in its path, pick up some sand that it could not carry before, transport it to a point beyond the crest of the mound where its speed falls off, and drop it there (Figure 2). In this way the wind protects the beach by building a dune, which will migrate downwind.

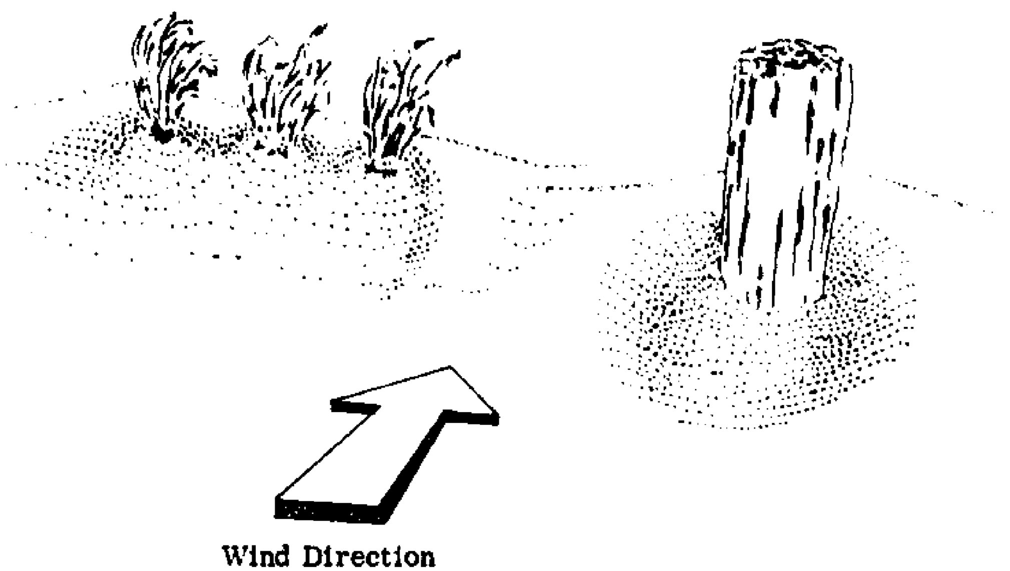


FIGURE 2

WIND SCOUR AROUND OBSTACLES

Structures located on a sandy beach will affect the wind direction and speed in their immediate vicinity. Zoning, building codes and permits for such structures should take this into account and also consider the fact that one of the best types of natural protection is a stable, well-developed dune. Bulldozing a dune to flatten a beach for the "view" is an invitation to disaster that may not be felt until the next hurricane.

Sand fences work as snow fences do, using the principle just described. A sudden decrease in wind speed on the downwind side of the fence, brought on by the turbulence the fence creates, causes the precipitation of the sand being carried. Thus, a dune can be generated where it is wanted, or a road can be kept free of encroachment by sand. The orientation of the dune will be along the fence even if the wind is not directly into it.

Large buildings on the beach may have a significant effect upon the wind direction over a considerable area; plans for them should be examined with this in mind.

The stabilization of dunes has received considerable attention [6h]. The best method, as in most cases, is to give a planned assist in the way that nature gives stability to a dune—by encouraging or even planting vegetation whose roots will do the job. The types of plants and how best to employ them are described in the reference literature [13, 14]. Work in this area is carried out at the Cape May Plant Materials Center in New Jersey.

The stability of a dune can be effectively destroyed by human abuse, such as by unlimited use of dune buggies, or by simply trampling the vegetation. Beach regulations and permits can prevent such damage.

As with all cases of human intervention, it is worthwhile to look into the possible consequences beyond those for which the intervention is designed. Needless to say, when sand is deliberately trapped or otherwise prevented from going where it would have gone, its natural destination is going to be without sand it would otherwise have received. In retaining sand for protective dunes, the shortage of sand that results downwind is seldom a problem, but the possibility should always be examined.

2.2.2 Waves and Swells

Waves and swells reaching sandy shores, so vulnerable to their impact, tend to create a protective barrier against their own action; thus, nature tends to stabilize the coast. Evidence of nature's way of achieving such a dynamic balance is seen not only along the south shores of Long Island, but along most of the East and Gulf Coasts of the United States. Like the oxidized surface that forms on a piece of metal and protects the interior metal from further corrosion, the barrier beach is formed, usually from sand washed down from the shore, and eventually protects the main coastline from the full impact of ocean waves. Dunes build along the barrier beach, and sometimes a bay of quiet water lies protected.

Inlets open when storms overwash and breach a dune; and nothing stays the same for long, except the major structure of a protective beach built by the sea itself. Even that yields to geologic change as shores recede over centuries, and major coastlines are innundated or advance through millennia.

What is of interest to this analysis in all of this is the dynamic interaction of waves and shore within the time frame of human plans, superimposed upon the longer cycles of geologic change, and how human activities can effect desirable results.

The annual cycle of wave effects upon a normal beach can be described simply, though variations for unusual sea conditions and irregular shoreline are to be expected. A beach between two rocky headlands performs most like the example to be described. The cycle is portrayed graphically in Figure 3.

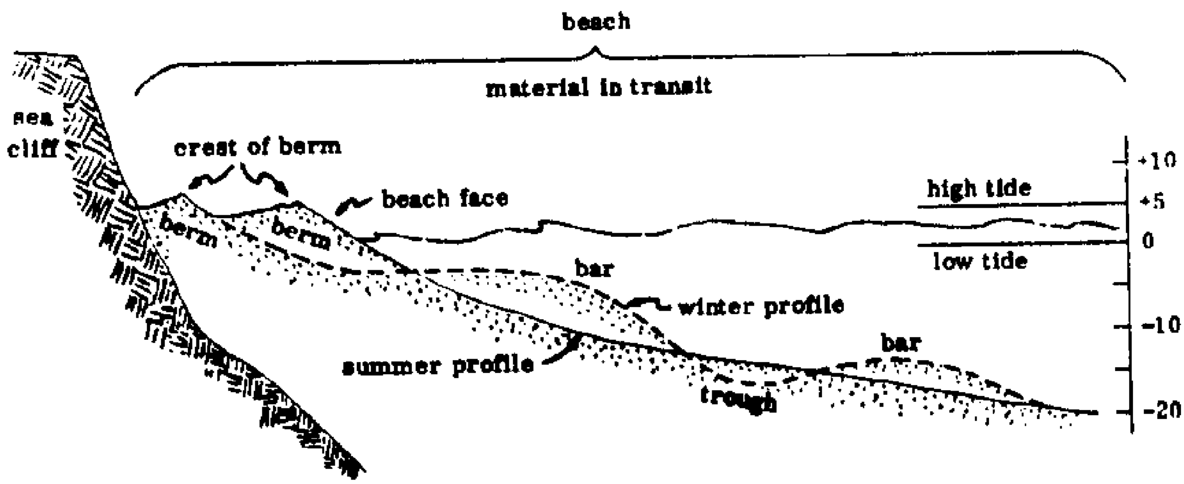


FIGURE 3

SEASONAL CHANGES IN THE DISTRIBUTION OF SAND

(From Waves and Beaches by Willard Bascom by Educational Services, Inc. Reproduced by permission of Doubleday and Company, Inc. [15].)

In general, the heavier seas, which occur primarily in winter, erode the beach face, transporting its sand offshore to a bar and steepening its slope[1/]. This process is essentially stable; the sand from the beach face reduces the slope of the submerged beach which then can dissipate more of the wave energy before waves reach the beach

[1/] The slope of a beach is also dependent upon the size of the sand grains.

face, reducing the energy to be expended there in effecting erosion. If continued indefinitely, the bar being built offshore becomes high enough to cause breakers, further reducing the energy reaching the beach face[1].

However, with the arrival of summer's moderate waves and swells, the process is reversed. Sand transported offshore by the winter waves is packed up from the bar and returned to the beach face by the lower, longer wave-length waves of summer. A full description of this mechanism is too detailed for presentation here, but the phenomenon can be found clearly explained in the very readable book, Waves and Beaches [15].

When discussing the transport of sand by wave action, the beach, by definition, includes the sand below water to where the depth is 30 feet (five fathoms). All the sand within this strip goes to make up the beach system—a dynamic, ever-shifting mass that is shaped and reshaped by the wave action and currents.

Dredging that removes sand from a bar deprives the exposed part of the beach of the material it requires for restoration after the winter erosion. Sometimes, however, sand is carried by wave action and currents into deeper water where natural forces cannot return it to the beach face or to the berm. Such sand is lost to the beach unless dredged. It serves as a good source for beach replenishment through human assist. In tests conducted at Sea Girt, New Jersey, the Corps demonstrated the technical, but not necessarily economical, feasibility of using offshore sand for beach nourishment and pointed out several ways in which the efficiency of the technique might be improved [16]. Surveys have shown that a considerable quantity of sand, adequate for beach nourishment, is located off the North Atlantic Coast [17]. To evaluate the economical and environmental feasibility of using offshore sand for specific Long Island beaches, a local survey is necessary.

Where the annual cycle is not operating due to natural or man-made features that prevent it from doing so, several structures have been developed to protect the beach from wave forces.

1/ Dr. C. L. McCormick of Southampton College has other views on this [2].

Although an expensive solution, at one time rejected for the south shore due to its cost [18b], breakwaters are sometimes constructed parallel to the beach at water depths beyond those common to the seaward end of jetties and groins. By absorbing the full impact of the waves, they create a region of relatively calm water between themselves and the beach that is useful for boat harbors and water sports as well as for protection of the beach. However, as a result of the same mechanism as that described for sand fences and the formation of a dune, sand is deposited on the landward side of the breakwater where the wave forces transporting it have been dissipated. Sufficient sand may be trapped there eventually to produce a land bridge or a "tombolo" between the breakwater and the beach [6n].

Bulkheads, revetments and seawalls are structures at the water's edge that contain the earth behind them and absorb the wave energies. They are often used to protect high-valued facilities that must be located adjacent to the waterfront. They are also useful as armament to protect the base of bluffs from wave attack. Certain designs can minimize but probably not eliminate the tendency for sand to be scoured away from the face of these structures.

2.2.3 Tides

Tides on Long Island produce several important effects. They cause periodic inundation of wetlands to the benefit of the biological system currently established there. They cause the periodic flushing of the backbays, thereby enhancing water quality, transferring nutrients and biota between ocean and bay, and maintaining the salinity regime. But they cause shoals to form opposite inlets through which they pass in performing these inundation and flushing functions.

The shoaling effect opposite inlets is particularly relevant to coastal stabilization and protection problems. Unless it is controlled, the inundation and flushing functions of tides will diminish with many undesirable effects far from the inlet.

The ocean tide south of the barrier beaches rises faster than the water in the bays, because the inlets cannot pass enough water to the bays to keep the water there at the same level. The difference in level causes the water to flow through the inlet at an increased speed, so it transports sand that it can pick up and carry at that speed until it reaches the bay. Once inside the bay, the channel widens, the speed decreases, and sand that can no longer be supported drops to the bottom of the bay to form a shoal.

When the tide is on the ebb, the action is reversed, and sand is deposited just outside the mouth of the inlet. These shoals eventually restrict the passage of water into and out of the inlet at either end, into narrow channels affecting the erosion of the shores near the inlet mouth. Littoral drift (see next section), when it is of sufficient magnitude, further complicates the transfer of water through the inlet into the bay.

Human action that can be taken to keep the inlets free of shoals produced by tides is limited to dredging. As always with dredging projects, a major consideration is the selection of a favorable place to deposit the spoil [1ℓ].

2.2.4 Littoral Drift

Littoral drift is the coastwise flow of sand carried by currents that are the result of waves hitting the beach at an angle.

When a wave impacts a beach at an angle, it carries suspended sand up the beach face at that angle until it exhausts its energy and drops the sand. But on the way back down the face of the beach, the sand follows the most direct path. The path of sand grains carried repeatedly up the face of a beach by waves arriving at an angle to the beach and then washed back down the face is hence a sawtooth shape with one edge inclined in the direction of original impact and the other (the return) perpendicular to the shoreline. The direction toward which the original impact is inclined becomes the direction of the littoral drift. With approximately 8,000 waves per day, if the distance from the place where the sand grain first enters the beach face and the place where it comes down again in the wave water rushing back to the sea is only a tenth of an inch, the grain will move seventy feet downdrift per day [15].

Longshore currents, set up by the waves' angular impact on the shore, also contribute to littoral drift by laterally moving sand that is placed momentarily in suspension by the turbulence produced when the waves impact upon the shore.

When the littoral drift reaches the mouth of an inlet, it enters the inlet as there is no beach face to intercept it. The beach is thus extended into the inlet. In some cases, erosion of the downdrift bank at about the same rate as accretion of the updrift bank causes the inlet to "migrate" downdrift.

If the downdrift bank does not erode, or does not erode fast enough, the inlet may eventually choke with sand and close [6g]. Littoral drift can then resume replenishment of downdrift beaches.

If the inlet must be kept open and stabilized, jetties can be built out into the ocean to trap the littoral drift and reduce the amount of sand flowing into the inlet; however, the jetties will also reduce the amount of sand moving to downdrift beaches where it is needed to replace sand constantly eroding therefrom.

Eventually, the jetty will fill and overflow, and, unless a sand bypassing system is installed, dredging may be necessary to keep the inlet open. A sand bypassing system would have the added favorable result of moving the sand to the downdrift beach where it can resume its natural westward travel.

A good example of these effects is furnished by Moriches and Shinnecock Inlets. During the century before these inlets were opened by storms, the net average regression of the shoreline between Shinnecock Inlet and a point about six miles west at Moriches Inlet was about 0.7 to 1.6 feet annually. After the inlets were opened and kept open, the net average regression of the same shoreline increased to about 6.8 feet annually [9]. Very large shoals of sand accumulated opposite the inlets on both the bay and ocean sides. The inlets acted something like a vacuum cleaner, sucking up the litteral drift and depositing it in two piles, inside and outside the inlets.

The direction of drift has been treated positively here for simplification. Actually, both the direction and magnitude of littoral drift vary greatly from season to season and even from day to day. On an annual basis, however, the net direction and magnitude of flow can be estimated. This is done primarily by periodically taking and comparing beach profiles, but also by emerging techniques such as the tracing of Xenon-133 and radioactive gold.

On the south shore ocean-front, the net littoral drift is westward and of increasing magnitude. For example, it is approximately zero at Montauk Point, 300,000 cubic yards annually at Moriches Inlet and 600,000 cubic yards annually at Fire Island Inlet. In the bays along the south and east shores, the direction of littoral drift is much more complex; however, its magnitude is not of major significance. Along the north shore, the general direction of littoral drift is generally eastward, but there are numerous local exceptions probably induced by eddies created by projecting headlands. The magnitude of littoral drift along the north shore has not been quantified, but it appears to be small.

The immediate source of the sand that constitutes the littoral drift is the beaches. But the sources of this beach sand are not easily quantified. For example, the barrier beaches west of Southampton are composed of material derived from erosion of the shore and headlands to the east, from wind erosion of the dunes and backshore areas, and possibly from material washed up from the ocean floor. Several estimates have been made of the amount of beach building material being supplied annually to the littoral environment through erosion of the bluffs at the east of the island. All indicate that the quality is somewhat less than 100,000 cubic yards per year [18b], a quantity nowhere near adequate to account for the much higher magnitudes observed farther westward. It therefore appears that a major portion of the littoral drift comes from a long-term general regression of the shoreline and possibly from the shelf region offshore.

2.3 THE LONG ISLAND SHORELINE

2.3.1 Reaches

In an analysis of erosion along the North Atlantic Coast [4a], the 551-mile shoreline of Nassau and Suffolk was divided into the five reaches depicted in Figure 4. That breakdown will be used here.

2.3.2 Ownership

Ownership patterns are summarized by reach in Table 3 and depicted in Figure 5. Note that about two-thirds of the shoreline is privately-owned and that most of the

TABLE 3

SHORELINE OWNERSHIP PATTERN

Reach	Ownership Pattern - in miles			
	Federal	Non-Federal Public	Private	Total
17 - South Shore oceanfront	14	36	58	108
18 - South Shore embayments 1/	15	67	90	172
19 - East Shore	4	40	124	168
20 - North Shore of Suffolk County	--	16	71	87
21 - North Shore of Nassau County	--	4	12	16
Total—Miles	33	163	355	551

1/Does not include embayments in the Town of Hempstead or east of Shinnicock.

Source: [4a].

remainder is public beach under non-federal ownership. The 6% under federal ownership consists almost entirely of Fire Island National Seashore and wildlife refuges.

2.3.3 Critical Erosion

The extent of critical erosion and the estimated cost of halting it are summarized by Reach in Table 4 and depicted in Figure 6. Note that the most critical erosion is found along the Atlantic and Sound, the bays being relatively stable.

TABLE 4

EROSION OF THE NASSAU-SUFFOLK SHORELINE
(in miles)

Reach	Length	Condition			Critical Erosion Breakdown		
		Non-eroding	Eroding		Priority	Miles	Cost of Protective Measures (millions)
			Non-critical	Critical			
17	108	0	0	108	1	91	$132
					2	17	25
18	172	0	172	0	-	-	25
19	168	0	93	75	3	75	60
20	87	0	0	87	2	87	92
21	16	0	7	9	3	9	11
Total	551	0	272	279	-	279	$320

Definitions:

Critical erosion areas. "Those areas where erosion presents a serious problem because the rate of erosion considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological and other relevant factors, indicates that action to halt such erosion may be justified."

Non-critical areas. "Areas where if development takes place without appropriate control, future problems will be generated."

Priority 1: "Areas where continued critical erosion is likely to endanger life or public safety within 5 years."

Priority 2: "Areas where continued critical erosion is likely to endanger property, scarce wildlife habitats, or landmarks of historical or natural significance within 5 years.

Priority 3: "Areas where continued critical erosion is likely to endanger life, public safety, property, scare wildlife habitats, or landmarks of historical or natural significance within 5 to 15 years."

Priority 4: "All other areas undergoing critical erosion."

Sources: [4a, 5].

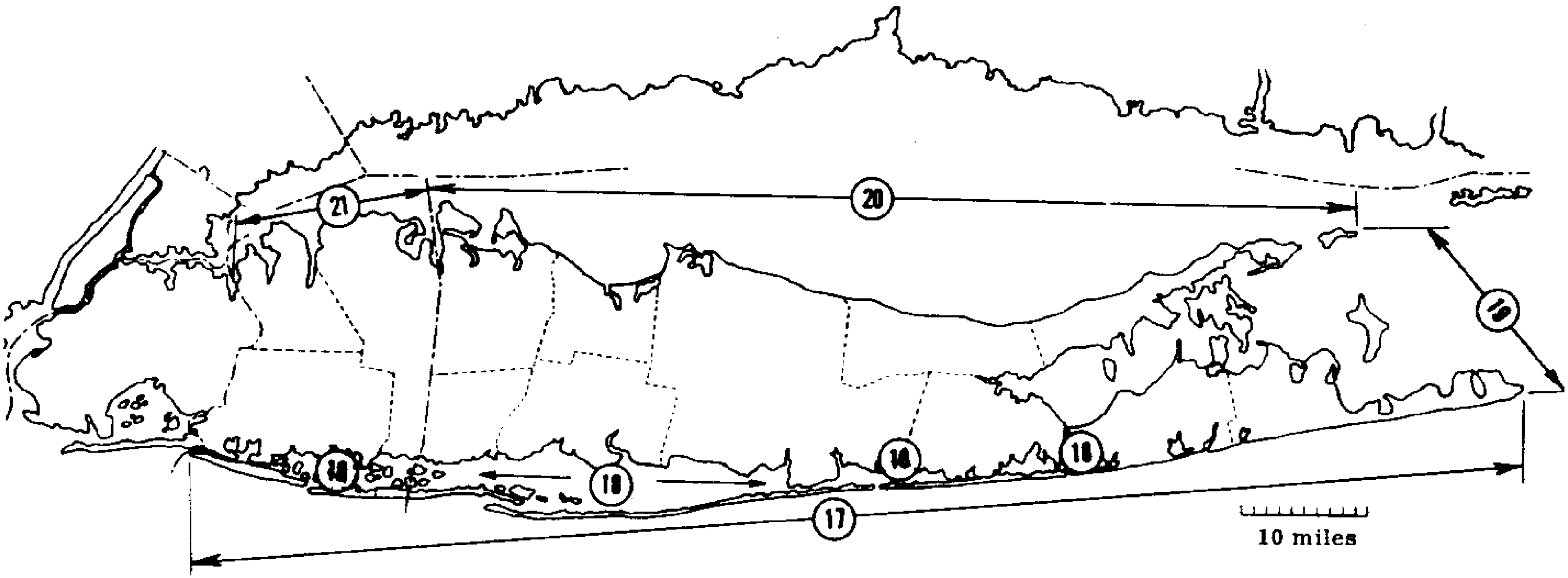


FIGURE 4

REACHES OF THE LONG ISLAND COASTLINE

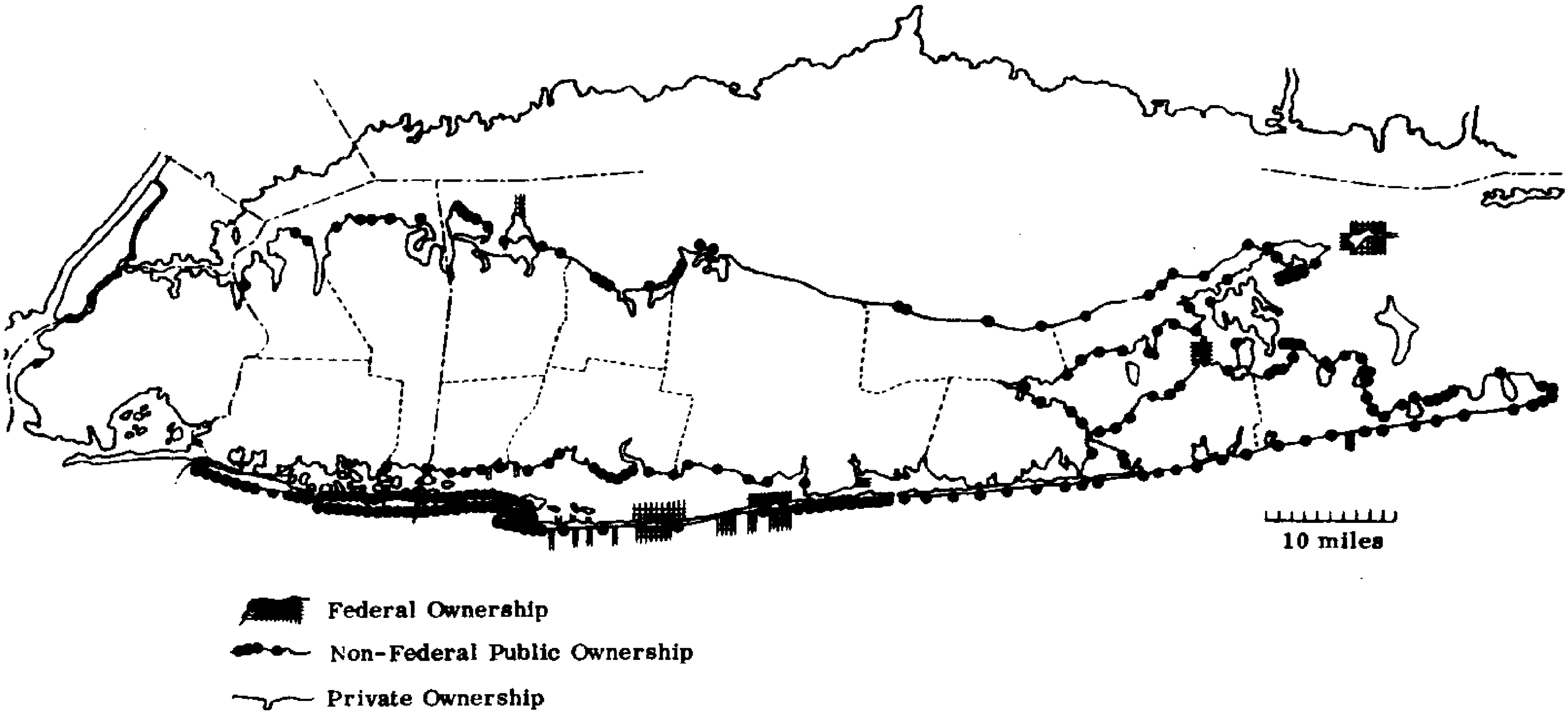
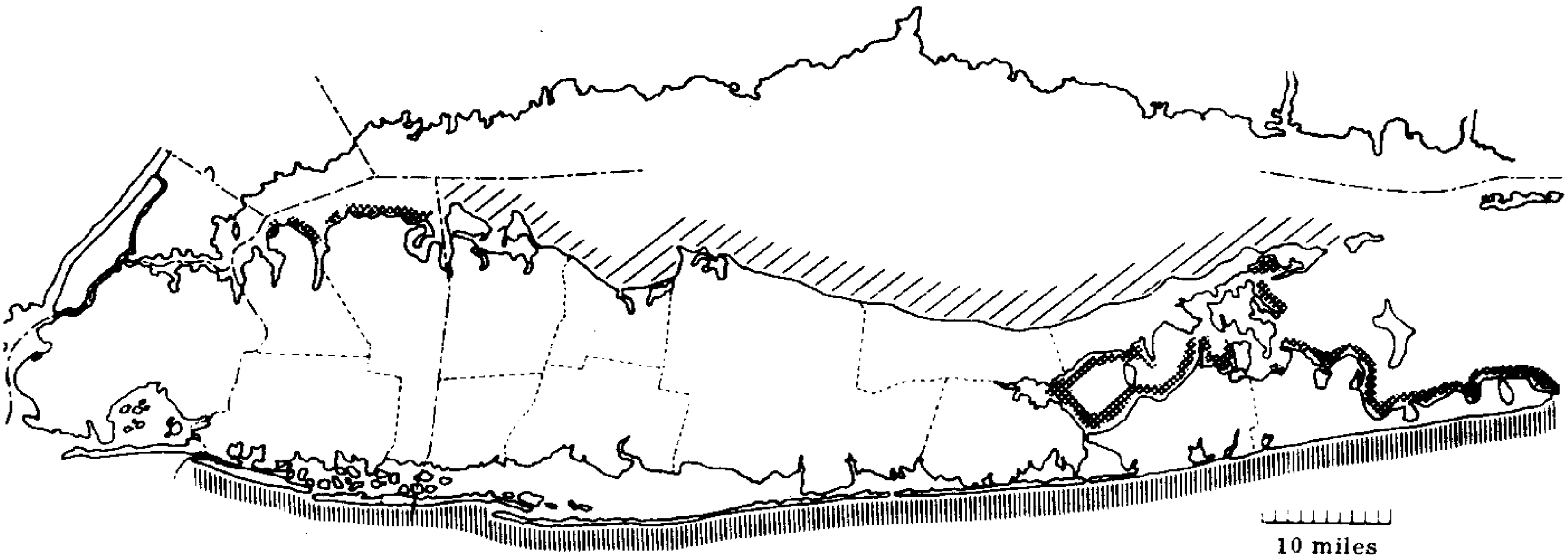


FIGURE 5

SHORELINE OWNERSHIP

Source: [2a]



Legend

- Priority 1
- Priority 2
- Priority 3

FIGURE 6

LOCATION OF CRITICAL EROSION

The entire south shore oceanfront is shown here as Priority 1. Actually, pockets of undeveloped shoreline, too small to depict here but aggregating 16% of the shoreline in this reach, are classified as Priority 2. These pockets are located in detail in The Regional Inventory Report [4a].

2.3.4 Potential Damages

The U.S. Army Corps of Engineers has estimated that a recurrence of the tidal flood of record—the 1938 hurricane for most of Long Island and the storm of September 12, 1960 for western Long Island and the bay areas—would inflict an estimated $170 million in damages on the south shore of Long Island in the bi-county area and $2 million on the north shore and eastern coast between the forks (1970 dollars) [8]. Some tidal flooding from either a tropical huricane or a northeaster will occur about every two years at some location on Long Island. Extensive damages will occur at a 10—12 year frequency and damages approaching those of a storm of record will occur at about a 30—40 year frequency. The storms can and have occurred throughout the year, but they usually strike between August and October. The heaviest damage is experienced from Hampton Beach to Southampton on the mainland and from Fire Island to Southampton on the barrier beaches.

In the following parts of this analysis, each reach will be considered in terms of its usage pattern, its physical condition, its history of past and current projects, its principal shore stabilization and protection problems, and alternative courses of action.

2.4 REACH 17 - SOUTH SHORE OCEANFRONT

2.4.1 Usage Pattern

Public beaches predominate along the western part of this 108-mile reach giving way to small residences and cottages in the central part of the reach and several large estates at Westhampton Beach and Southampton to the east. Atlantic shore frontage has received the greatest development for recreational purposes west of Fire Island Inlet, with the barrier beach east of the inlet less developed, probably as a result of its inaccessibility by direct land transportation. A bridge has been recently constructed across the inlet, and further development of Fire Island beach to accommodate the expected increased usage is underway.

Reach 17 represents significant government and private investment. Fire Island National Seashore and several state parks are located there. Among the latter are internationally known Jones Beach which records some 13 million visitor days annually. Private investment is reflected in the major developments along Atlantic Beach, Long

Beach and the extensive year-around and seasonal residences west of Fire Island National Seashore.

Direct human usage of this reach is perhaps exceeded in value, however, by nature's use upon which human needs indirectly depend—that is, the use of the barrier islands as natural bulwarks that protect the backbays and their shores from exposure to the forces of the open sea and its full tidal range.

2.4.2 Physical Condition

The barrier islands stretching eastward from East Rockaway Inlet to Southampton are still recovering from the overwash of storms dating back as far as 1962. Dune structure has not been adequately restored through natural processes. Dredging has supplied some needed sand where erosion was most pronounced; but, in maintaining inlets, dredging has been blamed for interrupting the littoral drift that could provide natural sand replenishment.

The inlets separating these islands would have closed or migrated westward over the years; Fire Island Inlet is nearly five miles west of where it was 150 years ago. Dredging of the channels and the building of jetties during the 1950's did temporarily stabilize the inlet positions; but, with the inlets trapping littoral drift, the projects must be repeated, and the effect upon natural beach replenishment has already been mentioned.

Eastward beyond Southampton the beaches with less developed dunes rise more steeply directly onto the main uplands of that part of the island (except at Mecox Bay) and are less altered from their condition of earlier times. For the last 15 or 20 miles to Montauk Point the cliffs continue as always to supply sand for beach replenishment downdrift, as they are gradually undercut and fall into the sea.

2.4.3 Projects

Shore stabilization projects on this reach—completed, underway, or authorized but not yet started—will be described from west to east. Unless otherwise indicated, all projects are federal projects under the U.S. Army Corps of Engineers.

Although it extends westward beyond Reach 17, a combined beach erosion control and hurricane project for Jamaica Bay and its barrier beach should be mentioned, as it is contiguous to Reach 17 and is a part of the south shore picture. The project provides for a hurricane barrier across the entrance to Jamaica Bay with a number of gates that will give a variable control over tidal effects, and other flood walls, dikes and levees, plus a beach nourishment program. A hydraulic model study was performed and the results used in the preconstruction planning, which has been essentially completed. However, the development of Jamaica Bay for multi-use conservation, residential and recreational purposes has been recommended [19] in a pattern that would require major modification of the authorized project. Pending a decision by the city, the project is being held in abeyance with construction funds omitted from the FY-72 budget.

A jetty protects the east side of East Rockaway Inlet, which forms the westward boundary of Reach 17, and a 12 x 250-foot channel has been dredged connecting the Long Beach Channel to the Atlantic Ocean. The project also included a jetty on the west side, but this was later considered unnecessary.

A jetty constructed in 1941 extends 5,000 feet southwest and south from Democrat Point to protect Fire Island Inlet. Dredging completed in 1953 produced a 10 x 250-foot channel through the inlet.

A combined beach erosion control and navigation improvement project was initially authorized in 1958 and largely completed by 1964. It called for another dredging of the Fire Island Inlet shoal to reduce the tidal currents on Oak Beach, to provide fill for Oak Beach and a feeder beach to the west, and fill for constructing a sand dike across the channel. In 1962 the project was modified by the River and Harbor Act to add a sand bypassing system to Fire Island Inlet. The system includes littoral and deposition reservoirs, a channel, dikes, a jetty and periodic transfer of sand to a feeder beach. A model study initiated in 1965 has been completed as part of the preconstruction planning. The modified project is now in the design phase.

The extensive stretch of shoreline between Fire Island Inlet and Montauk Point has been the subject of serious study. Natural forces and numerous projects have caused significant changes. One continuous barrier island stretched westward from Southampton to Fire Island Inlet until 1931 when Moriches Inlet was opened by a storm. Human efforts to stabilize the inlet have kept it open. Stone jetties have kept Shinnecock Inlet open after it was formed by the hurricane of 1938. As mentioned earlier, according to one estimate [9], the shoreline west of Shinnecock Inlet has been eroding at a rate six times faster than normal since the inlet was opened. Some idea of the cost of these projects is revealed in the following quotation, "Construction of 11 groins at Westhampton Beach in the Moriches Inlet to Shinnecock Inlet section was completed October 1966 at a cost of $2,334,955. Construction of another increment of work consisting of four additional groins and the placement of 6,000 feet of dune and beach fill along the shore at Westhampton, west of the eleven existing groin fields was initiated in 1969. Completion of the work is scheduled for fiscal year 1971 at an estimated cost of $2,945,000." [20]

Authorized "subject to certain conditions of local cooperation" in 1960, an extensive project will result in the widening of beaches to a minimum width of 100 feet at an elevation of 14 feet MSL in developed areas between Kismet and Mecox Bay, and the development of dunes to an elevation of 20 feet MSL wherever they are not already that high throughout the full extent of the barrier islands between Fire Island Inlet and Montauk Point. The federal government will partiicpate in the cost of periodic beach renourishment for up to ten years. "The estimated total cost of the project is $85,470,000 of which the federal share is estimated at $42,720,000 and the estimated annual cost for nourishment is $512,000, of which the federal share is estimated at $44,000 (July 1970 price level)." [20]

Protective structures were provided by local interests at Smith Point Park and at the western end of Southampton Beach in 1960.

2.4.4 Problems

Within the overall need of stabilizing and preserving the shore of Reach 17, there are three major problems. All are closely interrelated. One is the need to protect against tidal flooding damage and associated erosion caused principally by hurricanes. As stated earlier, damages predicted from a recurrence of the tidal flood of record along the south shore of Long Island have been estimated as about $170 million in 1970 dollars. A second problem involves the maintenance of channels through the inlets into the bays for navigation and tidal flushing purposes. The third problem is the requirement for some human action to halt the erosion of the beaches and dunes on the barrier islands. This erosion is to some extent due to the structures and dredging that are designed to maintain the inlets. The evolution of Fire Island Inlet, for example, and the history of recent efforts to keep it open and to protect Oak Beach all contribute to conditions today in that region that are far from stable. The jetty has filled and overflowed; the hopper dredge periodically works on the sand-choked channel depositing its spoil in the waters offshore, not certain of its contribution to the downdrift beaches.

2.4.5 Alternative Solutions

Potential management solutions [4c] to minimize the damaging effects of tidal flooding include:

(1) Flood plain management techniques to delineate potential areas of inundation and insure that this information is made available to localities, developers and property owners [4].

(2) Zoning regulations and building codes to control development.

(3) Improved warning, mobilization and evacuation measures to remove people, vehicles, boats and other readily moveable property from the threatened coast.

Potential engineering solutions [4b] to minimize todal flooding damage include:

(1) Positive protection structures such as barriers, sea walls, breakwaters, dikes, and placement of sand fill for raising and widening of beaches and construction of back-up dunes. Sand fill is especially appropriate for this reach because of the nature of the problem, the general availability of dredged sand, and the improved characteristics of the resulting beach for recreational purposes.

(2) Raising and/or relocating buildings, roads and bridges.

(3) Flood proofing and strengthening existing buildings and other structures.

A natural solution to reduce the starvation of the western beaches along Reach 17 would be to allow Shinnecock and Moriches Inlets to fill or migrate. This would allow the littoral drift to move westward as it did before the inlets were opened, and natural erosion of the western beaches would be partially replenished by the sands eroded from the Montauk cliffs as in geologic ages past [6g]. As pointed out earlier, it is unlikely that the cliffs would provide enough material to make up for the long range regression of this coastline.

If this natural solution, with the devastating effect it might have upon the backbays,[1] is not to be chosen, there are several other alternatives that call upon human intervention to accomplish the same end, while leaving the inlets open to perform their part in navigation and in promoting periodic inundation, biological exchange and flushing so essential to shellfish, other wildlife, and many human uses of the backbays.

One of these engineering alternatives is that of bypassing sand that reaches the eastern edge of an inlet across the inlet mouth to the beach on the western side where it can continue its westward movement, thus providing the sand necessary to the section of beach of which it forms a part at any given time.

Another engineering alternative is that of dredging sand from a place where it is not needed or wanted, and placing it on those sections of beach where natural erosion has not been replenished partially because sand was trapped by an inlet or by a jetty, groin or other structure. The grain-size distribution of sand in the shoals around these inlets has been found to be similar to that of the adjacent downdrift beach upon which the dredged shoal material could be deposited [8b, 22]. A "feeder beach" to replenish downdrift reaches can be created in this manner.

There appears to be no alternative to the periodic dredging of the inlets to keep them open; but for the deposition of the spoil the choice of location can be critical.

There is always the alternative of taking no action to restore or protect a beach that is obviously suffering erosion. With limited resource of time, money and sand, the decision as to whether a given case of erosion is worth action can always be made on the basis of the value of that stretch of beach for human and ecological purposes.

Alternatives for controlling the erosion of bluffs along the eastern end of Reach 17 are similar to those suggested later for Reach 20. If the bluff erosion is controlled, consideration must be given to making up the sand supplied from this source in replenishing beaches to the west.

2.5 REACH 18 - SOUTH SHORE BAYS

This 172-mile reach consists of the shores of Great South Bay and adjoining

[1] See earlier footnote at Section 1.5.6.

lesser bays and the interconnected shallow tidal waterways extending eastward from the Wantagh State Parkway Bridge to Shinnecook Bay.

2.5.1 Usage Pattern

Particularly on its inland side, the shore of Reach 18 is heavily developed with residential property, marinas and other major private financial investments. Most of the wetlands of Long Island are found in this area. Several publicly-owned parks and boat launching areas provide public access.

2.5.2 Physical Condition

With the maintenance of the inlets leading into the backbays, the condition of the bay shores has become largely a result of state, local and private projects at the shore, off shore, and upstream in the watershed. The activities being varied and localized, the shore conditions are also, but no critical erosion conditions exist.

2.5.3 Projects

Except for dredging associated with federal inlet maintenance projects identified earlier under Reach 17, no federal coastal stabilization and protection projects have been authorized for this reach. Dredging off the northern shore of Fire Island to provide sand for its beach, new parking fields, and dunes has left a trench of a depth reported to be up to 45 feet. The effects of this trench upon biological activity and tidal currents is apparently not fully known. Some wetlands, such as those bordering the marina at Patchoque Bay, have been fairly well preserved as part of land development plans. Extensive expanses of wetlands, however, have been lost to Venetian-type developments characterized by land fill, a network of bulkheaded canals and high density residential use.

2.5.4 Problems

From a shore stabilization and protection point of view, there are few significant problems located within the protected waters of this reach. The threat is from the outside and has two principal features. If the hydraulic properties of the inlets to the ocean are altered significantly either by nature or man, flushing, tidal elevations, salinity water quality and biological productivity can be significantly altered for better or for worse. Similarly, if the barrier beaches are breached by storm action, the breaching can have a significant effect on the entire system.

2.5.5 Alternative Solutions

Some have proposed a naturalist's approach to coast stabilization and protection so far as the barrier islands are concerned. The name given to this approach is "Overwash Maintenance." The concept gets its name from the assumption that the backbays and ecology in general are maintained best by allowing nature to purge the system occasionally with a severe storm that overwashes the barrier and floods the bay temporarily, washing into it sand that forms new wetlands.

There are some islands along the Atlantic Coast that have been maintaining their essentially wilderness condition through natural processes like this, plus the absence of human activity. These two factors seem to be required, however, if the concept is to be practical.

On Long Island, it may still be true that the long-term results for wildlife ecology might be served by such a policy as "Overwash Maintenance," but the human habitation of Long Island is very much dependent upon the bay tides, currents, salinity and temperature remaining more or less as they are now or changing in an intentional, controlled manner. Overwash Maintenance is not suggested for Long Island's south shore.

The preservation of the bays is thus dependent upon the maintenance of the inlets and dune system along Reach 17. The preservation of the shoreline from over-development is outside the scope of this study. It is a matter of coordinated development to meet the requirements of increased population with selective treatment of wetlands to retain those most needed, and the zoning necessary to assure that shoreline construction does not destroy the beauty of the bays.

2.6 REACH 19 - EASTERN FORKS

This 168-mile reach consists of the shores of the eastern forks of Long Island in Suffolk County from Orient Point on the north fork to Montauk Point on the south fork and the shores of Shelter, Plum and Gardiner Islands lying between them.

2.6.1 Usage Pattern

Residential and recreational usage predominates. Public bathing and other beach recreation is enjoyed at State parks at Orient Point, Hither Hills and Montauk Point. A county park at Cedar Point and the Morton National Wildlife Refuge on Jessup Neck are also available to the public, as are numerous boat harbors and marinas.

2.6.2 Physical Condition

Most of the shores of this reach are protected by the forks and islands. The upland land form is generally low, but it is interrupted frequently on the north shore of the south forks with high bluffs.

2.6.3 Projects

Numerous small groins and bulkheads have been provided by the state and by local interests.

A deep-water port installation has recently been proposed at Greenport. The village fathers have been supporting a plan to improve the economic status of Greenport by allowing the installation of deep-water port facilities to handle dry cargo vessels. They have formed the Greenport Industrial Development Agency to further this effort. However, there is sizable opposition to the plan in the Greenport area where The North Fork Free Enterprise has been carrying on a front page campaign to inform the public as to some of the consequences to be expected if the port plan is allowed to go ahead.

2.6.4 Problems

As depicted earlier in Table 3 and Figure 6, nearly half of this reach is subject to critical erosion, but the erosion is of lower priority than the erosion along most of the south and north shores. The critical erosion occurs along the shore areas that are fronted by bluffs. Solutions for this type of erosion are cited in Section 2.7.5.

2.7 REACH 20 - NORTH SHORE OF SUFFOLK COUNTY

2.7.1 Usage Pattern

Usage along this 87-mile reach is primarily residential and recreational. A favorite location for residences of all sizes is on the tops of high bluffs commanding a view of Long Island Sound. Some industrial and commercial installations are found in the vicinity of several small harbors and the seats of local government. Two large state parks in this reach are Sunken Meadow and Wildwood. The former has an average annual attendance of nearly two million and the latter has camping and trailer parks as well as a beach.

2.7.2 Physical Condition

Many of the beaches in this reach are generally narrow and rocky. About 90 percent of this reach is considered to be suffering critical erosion superimposed upon the natural geologic recession of the shoreline. As measured over the last 100 years, these shores have been receding at an average rate of from 1 to 2 feet per year, with some exceptions, such as Eatons Neck, Waterside Park, Fort Salonga, Crane Neck, Old Field Point, Mt. Misery and Mattituck Hills, where rates have been up to 3.5 feet per year [4a]. Some accretion has occurred where wave-built forms such as sand spits and barrier bars are found. In many cases, these have migrated considerable distances through the years.

2.7.3 Projects

State and local shore protection programs have included 236 groins; 14 jetties; about 46,500 feet of seawalls, revetments and bulkheads; and sand fill [4a].

2.7.4 Problems

The principal problems here are bluff erosion, shoaling of small harbors, and the narrowness and rocky composition of many of the beaches, conditions which reduce their desirability for bathing purposes.

2.7.5 Alternative Solutions

Bluff erosion can be minimized by controlling drainage at the top of the bluff, by building up the beach at the toe of the bluff or by reinforcing the toe with various types of armament. Shoaling can be controlled by dredging and jetties. Narrow rocky beaches can be improved by sand fill. All of these solutions are costly and have side effects which must be considered [4b]. In a completed Corps study of this reach, shore protection improvements were recommended at Sunken Meadow State Park [4a].

2.8 REACH 21 - NORTH SHORE OF NASSAU COUNTY

2.8.1 Usage Pattern

Usage along this short 16-mile reach is much the same as for Reach 20, with the exception that Hempstead Harbor, Manhasset Bay and Little Neck Bay reflect their closeness to the metropolitan area with greater density of installations and more intense commercial and industrial activity.

2.8.2 Physical Condition

Two types of shore conditions are worthy of note in this reach. One, due to natural forces, is the critical erosion along the high bluffs in Manhasset, Port Washington, Sands Point, Sea Cliff and Glen Cove and along the low beaches at Glen Cove and Center Island. The other type of condition, brought about by human activities, is typified by the pollution and extensive filling of Hempstead Harbor.

2.8.3 Projects

State and local interests have provided numerous groins, seawalls and bulkheads, and much sand fill. A navigation channel is maintained in Hempstead Harbor; the harbor has filled so much that at low tide the channel is the only body of water remaining.

2.8.4 Problems

As with Reach 20, shore bluffs are being undercut by erosion caused by wave attack and surface runoff. Residences and other structures at the top of these bluffs are threatened in some cases. The narrowness and rocky composition of many of the beaches reduce their desirability for bathing purposes. Solutions for problems of this type were cited in Section 2.7.5.

2.9 SUMMARY OF REACHES 17–21

Table 5 summarizes the preceding discussion for each reach.

TABLE 5

SUMMARY OF REACH ANALYSIS

	REACH 17	REACH 18	REACH 19	REACH 20	REACH 21
USAGE PATTERN	• Beaches • National seashore • State and county parks • Residences	• Wetlands • Commercial (Marinas, etc.) • Residential • State park beach • Private beaches • Fisheries	• Residential • Recreational • State parks • County park • Wetlands • National wildlife refuge • Marinas	• Residential • Recreational • State parks • Industrial • Commercial	• Residential • Recreational • Industrial • Commercial
PHYSICAL CONDITION	Barrier beaches recovering from overwash erosion and deprived of sand due to inlets trapping littoral drift	No critical erosion	• About 45% critical erosion principally at bluffs along north shore of south fork.	• About 90% critical erosion of shore especially along high bluffs and low beaches • Narrow, rocky beaches	• Critical erosion along high bluffs and low beaches • Excess of fill in Hempstead Harbor • Narrow, rocky beaches
PROJECTS	• Dredging inlets • Sand bypassing • Dune restoration • State park expansion • Groin construction • Jetty construction	State and local beach maintenance, and commercial and residential waterfront structures: bulkheads, docks, slips	• State and local protective structures and groins and jetties • Greenport deep water port controversy	State and local construction of groins, jetties and sea wall, revetments and bulkheads, sand fill and marinas	State and local construction of groins, sea walls and bulkheads and sand fill
PROBLEMS	• Hurricane erosion and inundation • Sand shortage on dunes and beaches • Sand excess at and in inlets	Increasing population and coordination of individual projects in comprehensive planning in the interest of users and wildlife	Coordination of regional development as its requirements impact the shore	• Shore bluffs being undercut • Shoaling in small harbors • Narrow, rocky beaches	Same as for Reach 20
ALTERNATIVE SOLUTIONS	• Beach and dune restoration and preservation • Beach nourishment in eroded areas • Dredging and fill • Sand bypassing	• Zoning • Permits • Acquisition • Condemnation	• Zoning • Permits • Acquisition • Condemnation	• Beach nourishment or armament to protect the toe of bluffs • Dredging and/or jetties to minimize shoaling effects • Beach nourishment to provide wider, sandy beaches	Same as for Reach 20

SECTION 3 - DATA COLLECTION AND RESEARCH NEEDS

During the analysis in Section 2, several data collection and research needs were identified:

- Coastal values. Data on the current and future usage of the coastline for a variety of purposes, and projections of likely future demands, are required to develop a well-formed multi-use perspective of coastal values. Without such a fundamental perspective, the significance of stabilizing, enhancing or ignoring selected reaches cannot be adequately appreciated. (Note that this usage data and projections have a much wider application to all aspects of comprehensive coastal planning than can be reflected in this report, which is focusing on just one aspect of that planning.)
- Offshore sand inventory. This type of inventory will be required at a level adequate to determine the practical availability of offshore sand for renourishing selected, high-value, eroding coastal reaches, particularly along the south and north shores.
- Predictive inlet models. Models will be needed to predict the critical relationships between potential changes in inlet conditions (whether caused by nature or man) and the physical, chemical and biological regimes of the backbays along the south shore.
- Land use management techniques. The feasibility of making better use of a wide variety of known land use management techniques for controlling usage of hazardous coastal reaches deserves considerable further investigation; the extent to which these techniques are currently being employed should be determined and opportunities for increased employment should be evaluated.

In later reports in this series, these needs will be further broken down and defined [1k], assigned priorities in relation to needs developed in other reports, and incorporated into a proposed problem-oriented marine resource program for Long Island [1f].

SECTION 4 - GUIDELINES

4.1 SOME BASIC CONSIDERATIONS

- Intensity of shoreline use. As measured by the intensity of its recreational usage and developmental pressures and by its importance in protecting the current, human-ecological environment, the 500-mile bi-county shoreline can lay impressive claim to being the most "valuable" shoreline of similar length in the nation. All major projections of future affluence, population, public values and liesure time point toward an acceleration of its increasing value.

- Shoreline condition. The shoreline is eroding to some degree almost everywhere in the bi-county area as part of long-range geologic trends. About half the erosion is "critical," i.e., action to halt it may be justified. Nearly half of the nation's "Priority 1 critical shoreline" (likely to endanger life or public safety within five years) is located in the bi-county area. The most significant problems, or potential problems, in our rated order of importance are:

  (1) Long-term regression of the shoreline, e.g., about two feet annually along the north shore.

  (2) Hurricane damage along the south shore through erosion, inundation and new inlet cutting along the barrier beaches; and potential inundation along the backbays, if the protective barrier beach is cut. Estimated damage is $170 million for a 30—40 year storm.

  (3) Maintenance of the south shore inlets which control tidal interchange and thereby influence currents, tidal elevations, biological exchange, shoaling, salinity and pollution levels in the backbays.

  (4) Oceanfront erosion caused by sand starvation downdrift of inlets.

  (5) Narrow rocky beaches on the north shore with uncaptured potential for absorbing an appreciable part of the very high demand for beach recreation.

  (6) Bluff erosion, especially along the north shore.

- Potential solutions. These include a combination of:

  (1) Engineering techniques—particularly beach nourishment, dune improvement and stabilization with vegetation, inlet stabilization and sand by-passing, and some groins and

local armament. Total cost has been estimated at $320 million of which $132 million is for Priority 1 shoreline on the south shore.

(2) Management techniques—particularly land use planning maps, regulatory controls such as zoning and building codes, flood-plain-management approaches such as delineation of hazardous areas, and storm warning services.

- Potential external effects. These should always be explicitly considered. Prominent examples are possible erosion elsewhere, possible impacts on backbay environments, and the value of benefits foregone by curtailing usage.

4.2 GUIDELINES

Policy and Planning Guidelines

- Along the north shore, the Council should:

  (1) As a general policy, accept the widespread shoreline regression as a long-term natural phenomenon beyond current practicable capability to control. Place primary emphasis here on land use techniques that influence occupancy and development of threatened reaches.

  (2) As major local exceptions to this general policy,

  — Encourage the creative enhancement or maintenance of heavily used beaches, preferably through sand nourishment techniques.

  — Encourage the maintenance of existing navigation channels connecting major embayments to the Sound.

- Along the south shore, the Council should:

  (1) Encourage programs to preserve and enhance the natural capability of the barrier islands to protect the environment of the backbays from sudden changes caused by storm breaching. Place primary emphasis here on dune stabilization and beach nourishment techniques.

  (2) Encourage projects to stabilize existing inlets at approximately their current dimensions and locations. Assure that stabilization techniques chosen include provision for adequate sand on downdrift beaches. Avoid substantial changes in these inlet characteristics unless explicitly justified by an analysis of the changes in the backbays.

(3) Encourage land use management measures to control the use and development of the barrier beaches in a way that reflects the public values involved.

- Along the shoreline encompassed within the eastern forks, the Council should avoid adopting general policy and planning guidelines. Although bluff erosion problems in this area can be substantial, the variable nature of the shoreline there requires that these problems be given site-by-site examination.

Research and Analysis Guidelines

The Council should:

- Encourage the U.S. Army Corps of Engineers to inventory offshore sand deposits in sufficient detail to assess the physical, ecological and economic feasibility of using these sands to maintain and enhance major Long Island beaches.
- Encourage the development of models to determine the relationships between inlet characteristics (number, location and size) and selected physical/chemical characteristics of the backbay system; the selected characteristics should include tidal elevations, salinity, currents, water quality, shoaling and scouring.
- Encourage an analysis of the feasibility of creativity employing inlet development and stabilization techniques to enhance the environment of the south shore bay system. Accomplish this analysis, as a part of the federally authorized but not yet funded Great South Bay Study.

APPENDIX A

REFERENCES

This appendix lists the references cited in brackets throughout the remainder of the report, generally in the order in which the references are first cited.

1. Regional Marine Resources Council, Nassau-Suffolk Planning Board, The Development of a Procedure and Knowledge Requirements for Marine Resource Planning. The Center for the Environment and Man, Inc. (formerly The Travelers Research Corporation), Hartford, Connecticut:

   a. Ellis, Robert H., et al., Functional Step One, The Classification of Marine Resources Problems of Nassau and Suffolk Counties, May 1969.

   b. Smith, Frank A., et al., Fourteen Selected Marine Resource Problems of Long Island, New York: Descriptive Evaluations, January 1970.

   c. Cheney, Philip B., Functional Step Two, Knowledge Requirements, February 1970.

   d. Ortolano, Leonard, Quality Standards for the Coastal Waters of Long Island, New York, A Presentation to the Marine Resources Council, Nassau-Suffolk Regional Planning Board under Sea Grant Project GH-63, National Science Foundation, April 1970.

   e. Ortolano, Leonard and Philip S. Brown, Jr., The Movement and Quality of Coastal Waters: A Review of Models Relevant to Long Island, New York, July 1970.

   f. Cheney, Philip B., High Priority Research and Data Needs, Interim Functional Step Four, November 1970.

   g. McGuinness, W.V., Jr., and R. Pitchai, Integrated Water Supply and Waste Water Disposal on Long Island, February 1972.

   h. Bartholomew, F. L. and W. V. McGuinness, Jr., Coast Stabilization and Protection on Long Island, February 1972.

   i. Dowd, Richard M., Dredging on Long Island, February 1972.

   j. Green, Ralph F., Wetlands on Long Island, February 1972.

   k. McGuinness, W. V., Jr., State of the Art for Selected Marine Resources Problems on Long Island, February 1972.

   l. Pitchai, R. and W. V. McGuinness, Jr., A Proposed Problem-Oriented Marine Research Program for Long Island, February 1972.

   m. Ellis, R. H., et al., Guidelines for Marine Resources Planning and Policy on Long Island, February 1972.

   n. Ellis, R. H., et al., The Design of a Management Information System for Coastal Resources Planning, February 1972.

2. McCormick, C.L., Conceptual Model of the Beach and Barrier Islands on the South Shore of Eastern Long Island, June 1971.

3. Renshaw, Clarence, "The Beaches of Long Island," Shore and Beach, October 1969, p. 50ff.

4. U.S. Army Corps of Engineers, The National Shoreline Study, 1971.

   a. Regional Inventory Report, North Atlantic Region.

   b. Shore Protection Guidelines

   c. Shore Management Guidelines

   d. Report on the National Shoreline Study

5. Personal correspondence and contact between W. V. McGuinness, Jr., and Messrs. Nersesian and Pagano, New York District, U.S. Army Corps of Engineers, December 1971.

6. U.S. Army Corps of Engineers, reports of the Beach Erosion Board (Coastal Engineering Research Laboratory since 1963).

   a. Allen, R.H. and E.L. Spooner, Annotated Bibliography of BEB and CERC Publications, MP 1-68, July 1968.

   b. Hall, Jay V., Jr., Artificially Nourished and Constructed Beaches, TM 29, AD 009480, December 1952.

   c. Rector, Ralph L., Laboratory Study of Equilibrium Profile of Beaches, TM 41, AD 046515, August 1954.

   d. Bruun, Per, Coastal Erosion and the Development of Beach Profiles, TM 44, AD 040418, June 1954.

   e. Scott, Theodore, Sand Movement by Waves, TM 48, AD 049232, August 1954.

   f. Krumbein, W.C., Statistical Significance of Beach Sampling Methods, TM 50, AD 046516, August 1954.

   g. Saville, Thorndike, Jr. and Joseph M. Caldwell, Preliminary Report: Laboratory Study of the Effects of an Uncontrolled Inlet on the Adjacent Beaches, TM 94, May 1957.

   h. Davis, John H., Dune Formation and Stabilization by Vegetation and Plantings, TM 101, AD 150543, October 1957.

   i. Horiscawa, Kiyoshi, and H. W. Shen, Sand Movement by Wind Action (on the Characteristics of Sand Traps), TM 119, AD 246157, August 1960.

   j. Vesper, William H., Behavior of Beach Fill and Borrow Area at Prospect Beach, West Haven, Connecticut, TM 127, AD 266262, August 1961.

   k. Taney, Norman E., Geomorphology of the South Shore of Long Island, TM 128, AD 266264, September 1961.

   l. Taney, Norman E., Littoral Materials of the South Shore of Long Island, New York, TM 129, AD 271022, November 1961.

m. Krumbein, W.C., The Analysis of Observational Data from Natural Beaches. TM 130, AD 271024, November 1961.

n. Shore Protection Planning and Design, TR 4, 3rd edition, Washington: U.S. Government Printing Office, 1966.

o. Caldwell, Joseph M., Coastal Processes and Beach Erosion, R 1—67, January 1967.

7. Nassau-Suffolk Regional Planning Board, Hauppauge, New York.

a. The Status and Potential of the Marine Environment, December 1966.

b. Existing Land Use, February 1968.

c. Nassau-Suffolk Comprehensive Development Plan (summary), July 1970.

8. North Atlantic Regional Water Resources Study Coordinating Committee, Appendix U—Coastal and Estuarine Areas, prepared by The Center for the Environment and Man, Inc., Hartford, Connecticut, 1971.

9. McCormick, C.L., A Probable Cause for Some Changes in the Beach Erosion Rates on Long Island, March 1971.

10. State of New York, 1971—1972, Regular Sessions in Assembly, "An Act to Amend the County Law, in Relation to Authorizing the Creation of County Hurricane Protection, Flood and Shoreline Erosion Control Districts in the County of Suffolk."

11. "General Clarke enlarges Corps' environmental role," Engineering News Record, April 16, 1970, pp. 28 and 34.

12. Wiegel, R.L., Oceanographic engineering, Englewood Cliffs, N.J., 1964.

13. U.S. Department of Agriculture, Soil Conservation Service, Study of Need for a Plant Materials Center in Coastal Plain Area, 1963.

14. U.S. Department of Agriculture, Soil Conservation Service, Long Range Program for the Cape May Plant Materials Center, 1966.

15. Bascom, Willard, Waves and Beaches, New York: Anchor Doubleday, 1964.

16. Mauriello, Louis J., "Beach Rehabilitation by Hopper Dredge," Waterways Division Journal of the American Society of Civil Engineers, May 1968.

17. Duane, David B., "A Study of New Jersey and Northern New England Coastal Waters," Shore and Beach, October 1969.

18. U.S. House of Representatives, House Documents:

a. No. 411, 84th Congress, 2nd Session, Fire Island Inlet to Jones Inlet, Long Island, N.Y., Cooperative Beach Erosion Control Study, 1956.

b. No. 425, 86th Congress, 2nd Session, South Shore of Long Island from Fire Island Inlet to Montauk Point, New York, Beach Erosion Control Study and Hurricane Survey, 1960.

c. No. 115, 89th Congress, 1st Session, Atlantic Coast of Long Island, Fire Island Inlet and Shore Westerly to Jones Inlet, New York, 1965.

d. No. 215, 89th Congress, 1st Session, Atlantic Coast of New York City from East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, New York, 1965.

e. No. 191, 90th Congress, 1st Session, Jones Inlet to Montauk Point, New York (Remaining Areas), 1967.

19. National Academy of Sciences National Academy of Engineering, Environmental Studies Board, Jamaica Bay and Kennedy Airport (a Multidisciplinary Study), 2 volumes, January 1971.

20. U.S. Army Corps of Engineers, North Atlantic Division, Water Resources Development by the U.S. Army Corps of Engineers in New York, January 1971.

21. U.S. Water Resources Council, Regulation of Flood Hazard Areas to Reduce Flood Losses, Volume Two (Part VI—Coastal Regulations), prepared by the University of Wisconsin (a pending report).

22. McCormick, C.L., Sediment Distribution on the Ebb and Flood Tidal Deltas, Shinnecock Inlet, July 1971

23. U.S. Army Corps of Engineers, Shore Protection Program, July 1970.

24. New York State Office of Planning Coordination, Metropolitan District Office, Outdoor Recreation on Long Island, March 1971.

25. U.S. Army Corps of Engineers, Waterways Experiment Station, Annual Summary of Investigations in Support of the Civil Works Program for Calendar Year 1969, Vicksburg, Mississippi, June 1970.

26. U.S. Army Corps of Engineers, Waterways Experiment Station, Channel Improvement, Fire Island Inlet, New York; Hydraulic Model Investigation, Vicksburg, Mississippi, November 1969.

27. Hydroscience, Inc., The Influence of Freeport Wastes on Water Quality in Hempstead Bay and Requirements for Ocean Disposal, Leonia, New Jersey, July 1969.

28. Berg, Dennis W., Factors Affecting Beach Nourishment Requirements, Presque Isle Peninsula, Erie, Pennsylvania, Pub. No. 13, Great Lakes Research Division, University of Michigan, AD 631520, 1965.

29. Berg, Dennis W., and David B. Duane, "Effect of Particle Size and Distribution on Stability of Artificially Filled Beach, Presque Isle Peninsula, Pennsylvania," Proc. 11th Conference Great Lakes Res. 1968, International Association Great Lakes Research 161—178, AD 694-204.

30. Cronin, L. Eugene, et al., Effects of Engineering Activities in Coastal Ecology prepared for the U.S. Army Corps of Engineers, September 1969.

31. Galvin, Cyril J., Jr., "Longshore Current Velocity: A Review of Theory and Data" Reviews of Geophysics, Vol. 5, No. 3, AD 672-614, August 1967.

32. Nordin, Carl F., Jr., Statistical Properties of Dune Profiles, Geological Survey Professional Paper 562-F, Washington: U.S. Government Printing Office, 1971.

33. Temporary State Commission on Protection and Preservation of the Atlantic Shore Front, The Protection and Preservation of the Atlantic Shore Front of the State of New York, July 1962.

34. U.S. Army Engineer Waterways Experiment Station, Publications Available for Purchase, Vicksburg, Mississippi, January 1971.